Introduction to ITS and Safety

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### Intelligent Transportation Systems

- Harnesses new technology to improve the safety, efficiency, and convenience of transportation.
- Systems in which information and communication technologies are applied.
  - Infrastructure, vehicles and users
  - Traffic management and mobility management.
- Some examples
  - Security CCTV cameras
  - Automatic incident detection
  - Electronic tolling
  - Variable message signs
  - Vehicles with navigation products
  - Emergency notification systems
  - Cross-border credentials checking
  - Automatic number plate tracking
  - and many more

### Some Benefits
- Improved safety
- Reduced congestion
- Reduced emissions
- Reduced travel times
- Improved reliability
- Enhanced access and quality of life
- Crash prevention
- Cost savings for commercial vehicle operations
- Enhanced travel options
Intelligent Transportation Systems - Global Trends

Number of research studies by year (in the last 25 years)
Source: Web of Science

Number of research studies by application areas (in the last 25 years)
Source: Web of Science
Number of research studies by country (in the last 25 years)
Source: Web of Science
Intelligent Transportation Systems – Trends in the USA

Freeways
• 67% length of freeways covered by CCTV cameras.
• Over 62% of agencies use radar.
• Over 33% of agencies use loop detectors
• Use of Bluetooth increased significantly from 24 percent in 2010 to 52 percent in 2016.

Arterials
• Deployment of traffic adaptive signals increased significantly from 23 percent of agencies, up from only 2 percent in 2010.
• More than three quarters of the arterial agencies reported the use of video imaging detectors, up from 58 percent in 2010.

Transit
• The use of AVL on fixed route buses increased to 76 percent of transit agencies, up from 54 percent in 2010.
ITS - History

Can you imagine that a barking dog screwed up traffic all afternoon?

• **Preparation (1925 – 1980)**
  - Electric traffic signals (sonar actuated) – perceived as first ITS deployment in the world (Baltimore, USA).
  - Computer controlled intersections (1960s)
  - Electronic Route Guidance System (1970s) – radio-based and in-vehicle (two-way communication)
  - Beginning of microprocessor and GPS technologies

• Focus was more on building roads than technologies

ITS - History

• Feasibility Phase (1980-1995) – Led by Europe, US and Japan
  • In Europe, 19 countries established the PROMETHEUS (Program for European Traffic with Efficiency and Unprecedented Safety) project.

  • Vehicles with cameras and processors
    • Automatic road and lane following,
    • Maintaining safe distance from the vehicle in front
    • Collision avoidance
    • Lane-changing and overtaking

  • Communication systems and telematics

Product Development (1995-present)

• Large-scale integration and deployment
• Data-driven
Sensors

• Classification of Sensor Technology
  • Based on functional principle
    • Mobile Sensors
      • Inbuilt to each individual vehicle (GPS receivers, acoustic/ultrasonic sensors, Bluetooth)
    • Point Sensors
      • Mounted at fixed locations along the roadway and observes traffic only at this particular location (Inductive Loop detectors, pneumatic tubes, RFID technology)
    • Space Sensors
      • Ability to take snapshots of traffic across space (Drone/Satellite photography)
  • Based on implementation of sensor
    • Intrusive
      • Installation of sensing system affects existing infrastructure – pavement work (loop detectors, pneumatic tubes)
    • Nonintrusive
      • Installation does not impede traffic flow (RFID and VIPS technology)
    • Off-Roadway
      • Sensor not fixed on the roadway (GPS receivers, cell phones, drones, and satellites)
Sensors – Loop Detectors

- A coil (loop) of wire embedded in the road’s pavement connected to a detector that is situated in a signal cabinet which links the signal controller to the inductive loop.

How does it work?
- The loop is placed in the road surface.
- The loop creates a magnetic field.
- A vehicle passing over the loop disturbs the magnetic field.
- The electronics unit detects the disturbance.
Sensors – Loop Detectors

• **Data collected**
  • Time-stamped traffic counts with vehicle classification
  • Speed/Headway data

• **Advantages**
  • Regular monitoring under all weather conditions

• **Disadvantages**
  • Intrusive installation
  • Setup and maintenance cost
  • Failure due to pavement erosion
## Loop Detectors – Sample Data

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Loop Detector Data Analysis for Safety
Sensors – Video Image Processing System (VIPS)

- An image capturing system (mounted video camera), connected with a telecommunication system and processed using an image processing system

**How does it work?**
- Camera records traffic flowing on a section of the road
- Video footage is saved or transmitted to a processing centre
- Processing algorithms designate detection zones within the frame captured and detect vehicles within the detection zones.
Sensors – Video Image Processing System (VIPS)

• **Data collected**
  • Time-stamped traffic counts with vehicle classification
  • Speed/Headway data

• **Advantages**
  • Regular monitoring under all weather conditions
  • Non-intrusive and flexible in setting up detection zones, limits errors

• **Disadvantages**
  • Very expensive
  • Vulnerable to visual obstruction (inclement weather, sun glare)
VIPS - Automatic Road Enforcement

• **Speed cameras** that identify vehicles traveling over the legal speed limit. Many such devices use radar to detect a vehicle's speed or electromagnetic loops buried in each lane of the road.

• **Red light cameras** that detect vehicles that cross a stop line or designated stopping place while a red traffic light is showing.

• **Bus lane cameras** that identify vehicles traveling in lanes reserved for buses. In some jurisdictions, bus lanes can also be used by taxis or vehicles engaged in carpooling.

• **Level crossing cameras** that identify vehicles crossing railways at grade illegally.

• **High-occupancy vehicle lane** cameras that identify vehicles violating HOV requirements.
Over 14 million challans have been issued in Delhi in 32 months (2019-2021) with the help of 155 traffic cameras.

In 2020, around 1.1 million traffic rule violators were fined manually in Delhi, while over 6.9 million were caught through cameras.

In 2019 -- the pre-Covid days -- the figures were 5.5 million manually and around 2.3 million through cameras.

Only 15% of the violators paid the fines.
CCTV detection decreases crash duration by approximately 5 min.

For each fatal crash outcome that occurs, we might observe as many as 5,000 or more critical conflicts, and for each crash resulting in minor injury, we might observe 50 critical conflicts.

Critical conflicts can help us predict crashes; but what do they look like? - Advanced Mobility Analytics (amagroup.io)
Conflict Analysis

Time to Collision (TTC)
https://www.youtube.com/watch?v=Aj-u-E92lSA

Post Encroachment Time (PET)
https://www.youtube.com/watch?v=rSABRwcVvUU
## Conflict Analysis

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<td>Gap Time (GT)</td>
<td>Time lapse between completion of encroachment by turning vehicle and the arrival time of crossing vehicle if they continue with same speed and path.</td>
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<td>Encroachment Time (ET)</td>
<td>Time duration during which the turning vehicle infringes upon the right-of-way of through vehicle.</td>
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<td>Deceleration Rate (DR)</td>
<td>Rate at which crossing vehicle must decelerate to avoid collision.</td>
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<td>Proportion of Stopping Distance (PSD)</td>
<td>Ratio of distance available to manoeuvre to the distance remaining to the projected location of collision.</td>
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<tr>
<td>Post-Encroachment Time (PET)</td>
<td>Time lapse between end of encroachment of turning vehicle and the time that the through vehicle actually arrives at the potential point of collision.</td>
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<td>Initially Attempted Post-Encroachment Time (IAPT)</td>
<td>Time lapse between commencement of encroachment by turning vehicle plus the expected time for the through vehicle to reach the point of collision and the completion time of encroachment by turning vehicle.</td>
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<tr>
<td>Time to Collision (TTC)</td>
<td>Expected time for two vehicles to collide if they remain at their present speed and on the same path.</td>
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VIPS - Conflict Analysis
VIPS – Road condition monitoring

- Using probe vehicles to capture the images of the road network

- Detection of:
  - Potholes
  - Barricades
  - Water logging
  - Safety issues

https://map.novaeavenue.com

https://portal.novaeavenue.com
Sensors – Pneumatic Tubes

• Pneumatic Tubes
  • Portable traffic data collection devices made of rubber tubing and are ideal for short-term traffic engineering studies.

• How does it work?
  • A rubber tube with a diameter of about 1cm is placed on the surface of a road.
  • Passing vehicles press on the tube and the air inside the tube is pushed away.
  • One end of the tube is connected to a box that contains a membrane and an electrical switch.
  • Air pressure moves the membrane and engages the switch.
  • Box counts axles that travel over the tubes and stores the data for later analysis.
Sensors – Pneumatic Tubes

• **Data collected**
  • Time-stamped axle counts which collects vehicle classification, direction of flow, traffic counts,
  • Instantaneous Speed and headway data can be inferred

• **Advantages**
  • Low cost
  • Portable and reusable

• **Disadvantages**
  • Limited coverage and can not be used for regular measurements
  • Vulnerable to damage, inaccurate data collection and can be intrusive
Sensors – Others

- These devices are not as commonly used as the previous 3 stated, however are becoming more prevalent
  - Bluetooth and WiFi scanners
  - Global Positioning System (GPS)
  - Acoustic/Ultrasonic Sensor
  - Aerial/Satellite Imaging
  - Radar
  - Lidar
  - Radio-Frequency Identification Technology

Purpose

To collect data necessary to conduct traffic engineering studies such as:
- Speed Studies
- Volume Studies
- Travel time (Delay) Studies
- Origin-Destination Studies
- Safety

ITS – Crowdsourced Pervasive Traffic Data

• Exploring novel traffic management strategies

• Assisting data and infrastructure-poor countries leapfrog to digital infrastructure

• Developing methodologies for incorporating social media data into transport planning
Travel between Mumbai CST and Thane

Zonal trip productions during the morning peak hour (as a percentage of total demand)

Zonal trip attractions during the morning peak hour (as a percentage of total demand)

How to stop snarls? Noida says ‘Ok Google’

Noida to get IT-enabled traffic signals that swap colour to ease vehicular movement

Sensors to be installed at traffic signals in Thane to ease congestion, make travel smooth

Additional Material – Self Reading

Not part of the exam
ITS – Broad Categories

1. Advanced transportation management systems;
2. Advanced traveller information systems;
3. Advanced vehicle control systems;
4. Commercial and PT vehicle operations

Functions of these components can fully be realised depends on how data are collected and processed into useful information.
1. Advanced Transportation Management Systems (ATMS)

- Operate with a series of video and loop detectors, variable message signs, network signal and ramp meters, and incident control strategies.

- Data collection team
  - monitor traffic conditions

- Support systems
  - cameras, sensors, and electronic displays

- Real-time traffic control systems
  - using the information from the above two
  - send messages to electronic displays and control highway access
Speed Management – Part-time Speed Limits

Davey Warren, Office of Safety R&D, Federal Highway Administration
Speed Management - Variable Speed Limits (VSL)

VSL allows speeds to be dynamically changed to provide the most appropriate and safe speed for the prevailing conditions.

Example: VSL system determines that traffic in a particular section has slowed significantly, and sets progressively lower speed limits for upstream sections to ensure that there is a safe differential speed.
VSL - Benefits

• Originally introduced as a road safety measure.

• Also becoming widely recognised as a valuable tool for increasing vehicle throughput.

• Can also be used to reduce traffic noise at night.
Variable Message Signs – Downstream Hazard Warning
**Ramp Metering**

- A basic traffic light or a two-phase signal (red and green only, no yellow) light together with a signal controller that regulates the flow of traffic entering freeways according to current traffic conditions.

- Control aims at maximising the capacity of the freeway and prevent traffic flow breakdown and the onset of congestion.

- The metering system ensures that there is adequate headway between entering vehicles and that there are gaps in the outer lane to accommodate them.

- A 3-d simulation video on how ramp metering works

  https://www.youtube.com/watch?v=WLI4SwW5wZw
Ramp Metering

• Vehicles are temporarily ‘stored’ on the entry ramp and released at a ‘metered’ rate by a set of signals just upstream of the merge area.

• The signals operate on very short cycles to allow between 4 and 30 veh/min (depending upon the number of ramp lanes) to join the main flow.

• Vehicle sensors on both the ramp and the freeway carriageway measure the relative flows, and algorithm-based processors use this data to continuously adjust the rate of entry via the signal timing.

• Successful ramp metering requires integration of the freeway detection and control systems with the arterial road control system on the approaches to entry ramps.
Ramp Metering

2. Advanced Travellers Information System (ATIS)

• **Objective:** provide drivers with the right information at the right time and at the right location.

• **Pre-journey:** motorists who subscribe to an information system can be alerted to changes or conditions on their favoured routes by email, targeted SMS, traffic TV channel or telephoned advice from third-party providers.

• **En-route:** drivers in their vehicles can receive travel information and make timely decisions about changing or maintaining their route. It can be through VMS, drive-time radio, in-vehicle navigation systems, etc.

• **Benefits:**
  - Reduced public and private user costs through improved ability to plan or modify trips;
  - Integration of the public transport system into driver trip planning scenarios,
  - Reduced duration of congestion because drivers can be warned to avoid already congested routes.

Source: New York State Department of Transportation
3. Commercial and PT Operations

**Commercial Vehicles**
- Onboard monitoring
- Telematics
- Automatic vehicle location
- Roadside CVO safety inspections
- Weigh-In-Motion (WIM)
- Hazardous material planning and incident response
- First and Last mile
- ADAS
  - Adaptive cruise control
  - Lane keeping assist
  - Automated emergency braking
- Connected vehicles
- Truck platooning

**Public Transportation**
- Automatic vehicle location (AVL)
- Automatic passenger counters (APC)
- Transit signal priority
- Scheduling systems
- On-board announcements
- Third party apps
- Video surveillance
- Automated fare payments
- Engine and drivetrain monitoring
- GIS

[https://www.youtube.com/watch?v=twa_1sWQvP8](https://www.youtube.com/watch?v=twa_1sWQvP8)
**Our statement on Guwahati scooter accident**

We send our heartfelt wishes for Mr. Balwant’s son and hope for his quick and smooth recovery from this accident. Given the public speculation that this accident has generated, we want to share the facts about what happened.

We did a thorough investigation of the accident and the data clearly shows that the rider was *overspeeding* throughout the night, and that he was *braked in panic*, thereby *losing control of the vehicle*. There is nothing wrong with the vehicle.

Our operating system tracks various vehicle sensor data which we receive real time in our cloud. Below graph shows speed data for this incident for a 30 min duration till the accident time.

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**Guwahati accident: Ola gets into a squabble with user; ignites concerns about data privacy**

_Ola Electric drew massive backlash on social media for harvesting data and making it public on social platforms. Netizens sided with the user Balwant Singh who raised concern about the privacy pact between the company and its customers._
Emergency Vehicle Call/Notification System – eCall (Europe)

- Device installed in all vehicles that will automatically dial 112 in the event of a serious road accident.
- Wirelessly send airbag deployment and impact sensor information, as well as GPS coordinates to local emergency agencies.
- A manual call button is also provided.
- Reduced emergency response times by 40 percent in urban areas and by 50 percent in rural areas.
- Cost <100 Euros per new car

For more details:
- eSafety (eCall) – ITS Standards
- Compare Plans & Prices for OnStar and Connected Services

(3) HIGHWAY 3: M3 Crash - BMW Emergency call [with subtitles] – YouTube

iPhone Crash Detection:
https://www.youtube.com/watch?v=MZn6K44qfdU
4. Advanced Vehicles Control Systems (AVCS)

- In-vehicle sensors
  - Cues on the surroundings (through visuals and audio)
  - Help to react in dangerous situations in a faster and efficient way

- Examples:
  - Emergency brake assist
  - Forward collision warning
  - Advanced cruise control
  - Automated steering control for lane and road keeping
  - Fatigue detection
  - Distraction detection

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Average Lines of Software Code in Modern Luxury Vehicle Compared to Types of Aircraft

Source: Battelle. | GAO-16-350
Connected Vehicles

• Vehicles that can talk to each other, as well as roadside devices.

• **Cellular Vehicle to Everything (C-V2X)**
  • Mobile data networks to share information
  • Information shared includes traffic delays, rapid braking, slippery road conditions and distances between vehicles travelling in the same direction (known as headway distance).

• **Dedicated Short Range Communications (DSRC)**
  • Using a special radio frequency
  • Can ‘talk’ to each other over distances up to 1 km
  • Can operate anywhere, even in areas where there is no mobile phone reception
  • Drivers can be warned of risks on the road ahead, over the crests of hills or around bends.
Connected Vehicles - Benefits

- Reduction of **crashes by up to 25%** during winter weather due to weather traffic management applications on freeways.

- Reduction in **speed variations** between freeway segments by **18%-58%** and within freeway segments by **10%-47%**, resulting in fewer rear-end crashes.

- Fewer instances of hard braking and up to **89%** reduction in maximum deceleration in incident zones.

- Reduction in average network-wide **delay of up to 14%** due to alerts to incident zone workers.

- **Fuel savings of 2%-22%** when signal operations and freeway lane management are optimized for the environment.
Connected Vehicles - Applications

- Ambulance alerting system
  - Car drivers alerted about an approaching emergency vehicle and its path.
  - Sharing information like distance between vehicles on a real-time.

- Wrong-way driver alerting system
  - Car drivers get a pre-alert about the existence of a wrong-way-driver approaching

- Pedestrian alerting system

- Road condition alerting system
Connected Vehicles – Insurance Industry

- Predictive-modelling and machine-learning technologies, as well as real-time data streaming, providing among others information on driving speed, routes and time, are changing insurers' doing-of-business.

- Transition from being pure insurance product provider to becoming insurance-service hybrids.

- Personal and regional risk assessments using telematics.
- Fraudulent insurance claims.
- Dynamic risk profiles and improved customer segmentation.

- Future: Coaching on driver skills for fuel efficiency and safety, prediction of maintenance needs, advise to owners on best time to sell a car.
Advanced Driver Assistance Systems (ADAS)

- Airbags, seatbelts and all of the essential passive safety parts are standard equipment.
- Now cars are often equipped with new advanced active safety systems that can prevent accidents.
- ADAS are developed to automate, adapt, and enhance vehicle technology for safety and better driving.
- Designed to avoid crashes and collisions by offering technologies that alert the driver to problems, implementing safeguards, and taking control of the vehicle if necessary.

- Automate lighting
- Adaptive cruise control
- Collision avoidance
- Satellite navigation and traffic warnings
- Alert drivers to possible obstacles
- Assist in lane departure and lane centering
- Provide navigational assistance through smartphones, and provide other features.
Advanced Driver Assistance Systems (ADAS)

• Difference between ADAS and DAS: **Usage of Data**

• Early DAS systems include anti-lock braking system (ABS), electronic stability control (ESC), etc.

• ADAS relies on multiple data sources, including automotive imaging, LiDAR, radar, image processing, computer vision, and in-car networking.

• Additional inputs are possible from other sources (vehicle-to-vehicle or V2V communication) and infrastructure (vehicle-to-infrastructure or V2I communication)

**Current cars in India**

- Mahindra XUV 700
- MG Astor
- Honda City e: HEV
- MG Gloster
- Hyundai Tucson
Advanced Driver Assistance Systems (ADAS)

Passive ADAS Systems

Regardless of the number or types of sensors installed, in a PASSIVE ADAS system, the computer merely informs the driver of an unsafe condition. The driver must take action to prevent that condition from resulting in an accident. Typical warning methods include sounds and flashing lights, and sometimes even physical feedback, for example, a steering wheel that shakes to warn the driver that the lane they are moving into is occupied by another vehicle (blind spot detection).

Common Passive ADAS Functions Include:

- **ABS - Anti-lock Braking Systems**: Keep the car from skidding and turning when emergency braking is applied.
- **ESC - Electronic Stability Control**: Assists the driver in avoiding under or over-steering, especially during unexpected driving conditions.
- **TCS - Traction Control System**: Incorporates aspects of both ABS and ESC above, to assist the driver in maintaining adequate traction when negotiating turns and curves.
- **Back-up Camera**: Provides the driver a view behind the car, when parking or backing up.
- **LDW - Lane Departure Warning**: Alerts the driver if the vehicle is not keeping within its lane.
- **FCW - Forward Collision Warning**: Tells the driver to brake in order to avoid a collision ahead.
- **Blind Spot Detection**: Warns the driver that there is a vehicle in their blind spot.
- **Parking Assistance**: Warns the driver when their front or rear bumpers are approaching an object at low speeds, i.e. when maneuvering into a parking space.
Advanced Driver Assistance Systems (ADAS)

Active ADAS Systems

In an ACTIVE ADAS system, the vehicle takes direct action. Examples of Active ADAS functions include:

- **Automatic Emergency Braking**: Automatically brakes as required to avoid hitting a vehicle ahead or another object, including pedestrians, animals, or anything in the lane of travel.
- **Emergency Steering**: steers the car to avoid striking an object in the lane of travel.
- **Adaptive Cruise Control**: Adjusting cruise control speed to match vehicles ahead.
- **Lane Keeping Assist and Lane Centering**: Steering the car to stay centered in the lane.
- **Traffic Jam Assist**: Combines adaptive cruise control and Lane Keeping Assist to provide semi-automated driver help during dense traffic events, i.e., stop and go conditions due to lane closures, road construction, etc.
- **Self Parking**: Self-maneuvering into parking spaces.
Advanced Driver Assistance Systems (ADAS)

- **Level 0** - ADAS cannot control the car and can only provide information for the driver to interpret on their own.
  - Parking sensors
  - Surround-view
  - Traffic sign recognition
  - Lane departure warning
  - Night vision
  - Blind spot information system
  - Rear-cross traffic alert
  - Forward-collision warning.

- **Level 1 and 2** are very similar in that they both have the driver do most of the decision making.

- Level 1 can take control over one functionality and level 2 can take control over multiple to aid the driver.

  **Level 1**
  - Adaptive cruise control
  - Emergency brake assist
  - Automatic emergency brake assist
  - Lane-keeping, and lane centering.

  **Level 2**
  - Highway assist,
  - Autonomous obstacle avoidance
  - Autonomous parking.
Advanced Driver Assistance Systems (ADAS)

• **Level 3 – 5** are not fully defined and not in commercial usage.
  • Level 3 – Highway chauffeur
  • Level 4 – Automatic valet parking
  • Level 5 – Fully autonomous

- Level 0 - no automation;
- Level 1 - hands-on/shared control;
- Level 2 - hands-off;
- Level 3 - eyes off;
- Level 4 - mind off, and
- Level 5 - steering wheel optional.

H. Alghodhaifi, S. Lakshmanan: AV Evaluation: Comprehensive Survey on Modeling and Simulation Approaches
Advanced Driver Assistance Systems (ADAS)

• Predicted to be transformative, with a potential to improve productivity, reduce congestion and improve safety.

Success depends on:

• To what extent the drivers (riders?) trust them
• How people choose to use and interact with them, and the ensuing safety risk.
• How drivers of normal cars react to AVs

• Annual disengagement and accident reports submitted to The California Department of Motor Vehicles (DMV)
• Companies: Bosch, Delphi, Google, Mercedes Benz, Nissan, Volkswagen Group and Tesla
• Data provided:
  • Disengagement, Road type, Weather condition
  • Factors contributing to the disengagements
  • Reaction times (only Google and Mercedes Benz)
  • Accident information
### Reason for disengagement

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Connected and Automated Vehicles

• NSW - Partially automated vehicle trials findings | Transurban CAV trials

• Cooperative Intelligent Transport Initiative (CITI) Light Vehicle Study Driver Feedback (nsw.gov.au)
Connected and Automated Vehicles

- AV readiness ranking

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</table>

H. Alghodhaifi, S. Lakshmanan: AV Evaluation: Comprehensive Survey on Modeling and Simulation Approaches
Challenges

- Lack of transparency in sharing data
- Lack of coordination and communication between different agencies
- Too much reliance on manual and ad hoc traffic surveys
- Absence of national standards and practice codes
- Training of resources
- Financial constraints
- Focus on collecting data but not much on analysis
- Penetration of vehicles with advanced technologies is still low
- Cybersecurity risks
Challenges

Key Vehicle Interfaces That Could Be Exploited in a Vehicle Cyberattack

Average Lines of Software Code in Modern Luxury Vehicle Compared to Types of Aircraft

Source: GAO analysis of stakeholder interviews and Checkoway et al, 2011. | GAO-16-350

Source: Battelle. | GAO-16-350
When we provide traffic engineering solutions, a practitioner must be mindful of the many transport related issues that are present today such as:

- Congestion
- Pollution
- Safety (Crash rates)
- Equity and Accessibility

To assist in our solutions we can use models, which provide unique and consistent results, that depict human travel behaviour.....
Simulation Models

Experiment with actual system

Experiment with a model

Physical Model

Analytical Model

Simulation Model

*Simulation, Modeling & Analysis (3/e) by Law and Kelton, 2000, p. 4, Figure 1.1*
Simulation Models

**Macroscopic**
- Strategic high-level static modelling, used in planning. Predicts volumes on different routes. Uses travel time-volume functions (such as BPR)
  - [https://www.youtube.com/watch?v=OM6-PyjZsDY](https://www.youtube.com/watch?v=OM6-PyjZsDY)

**Mesoscopic**
- Dynamic route choice modelling to evaluate operational strategies. Uses traffic flow relationships such as speed-density and flow-density relationships.
  - [https://www.youtube.com/watch?v=iNrZNqCs2go](https://www.youtube.com/watch?v=iNrZNqCs2go)

**Microscopic**
- Models individual vehicle dynamics. Used to study merge areas, intersections, weaving etc.
  - [https://www.youtube.com/watch?v=IF_RoSlofyA](https://www.youtube.com/watch?v=IF_RoSlofyA)

**Interactive microsimulation tool**
- [http://www.martin-treiber.de/trafficSimulationDe_html5/onramp.html](http://www.martin-treiber.de/trafficSimulationDe_html5/onramp.html)
Simulation Models
Simulation Models

• Models should not be perfect, but it is important that they are *applicable*, and whether they are applicable for any given purpose (to answer a question or make a decision) must of course be investigated.

• We don’t want a perfect model unless we can afford it. The cost of producing a model should not exceed the value that the model adds in answering the question.

• “All models are wrong, but some are useful” by George Box, a famous statistician.
Simulation Models
**Simulation Modelling and Crash Severity**


- Freeway Network
- Speed variability decreases and robustness increases with increasing CAV penetration.
- Robustness of the driving behaviour increases with increased CAV penetration.
- The full-scale benefits of CAVs can only be achieved at 100 per cent CAV penetration.

**Impact of Automation in Public Transport**


- Urban Network
- Introducing automation only in buses can decrease average delay and TSTT by 13.37% and 7.87% respectively.
- The average speed of the network was also increased by 9.11%.

![Simulation Modelling and Crash Severity](image1)

![Impact of Automation in Public Transport](image2)
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<td>Dynamic message signs, 511 phone, 511 websites, and smart phone applications</td>
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</table>
Thank You
Sai Chand
saichand.transport@gmail.com
saichand@iitd.ac.in